# Forest Health Protection

## Pacific Southwest Region
## Northeastern California Shared Service Area

Date: August 15, 2019
File Code: 3420

To: District Ranger, American River Ranger District, Tahoe National Forest

Subject: Evaluation of insect and disease conditions within the Nyack Project (FHP Report NE19-02)

At the request of Kelly Pavlica, Silviculturist, American River Ranger District, Tahoe National Forest, Bill Woodruff, Plant Pathologist and Danny Cluck, Entomologist, conducted a field evaluation on July 1, 2019 of the Nyack Project. The objective of the visit was to evaluate the current forest health conditions within the project area, discuss what influence these conditions would have on stand management objectives and provide recommendations as appropriate. Kelly Pavlica and Rachel Bean, Harvest Inspector, accompanied us in the field.

Key findings:

- Overstocking is putting stands within and around the Nyack project at risk to high levels of bark beetle-caused tree mortality during periods of drought. Pine plantations and areas of root diseased white fir are most at risk.
- Several native forest insects and diseases are currently contributing to tree mortality including bark beetles and root disease.
- Mortality was highest for white fir, followed by ponderosa pine.
- The abundance of root diseased white fir is creating a hazard tree problem in some locations that are undeveloped camping areas.
- Thinning and prescribed fire are recommended to reduce stand density and reduce surface and ladder fuels. Specific recommendations are provided in this evaluation.

**Figure 1.** High density mixed conifer stand with shade-tolerant white fir and incense cedar dominating the understory. Nyack Project, 2019.

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## Description of the project area

The Nyack project is located in the general area around Blue Canyon, CA at an elevation of 3800 to 5800 feet (39.257592N and 120.650998W). Annual precipitation is approximately 45 to 70 inches depending on elevation. The forest type is Sierra Nevada mixed conifer with ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Psuedotsuga menziesii*), sugar pine (*Pinus lambertiana*), incense-cedar (*Calocedrus decurrens*), white fir (*Abies concolor*) and black oak (*Quercus kelloggii*). There are also ponderosa pine plantations in various locations. White fir and incense-cedar are the primary understory species to the exclusion of ponderosa pine and black oak regeneration (Figure 1). Management objectives for this area are to reduce stand density and reduce surface and ladder fuels.

## Observations

Stand density for most forested areas within and adjacent to the Nyack project is above recommended stocking levels that would increase stand resiliency to insects, diseases and drought. Recent high-level tree mortality is also a concern for long-term fuel loading and the immediate threat of tree hazards to some roads (Forest Service and County) and undeveloped campsites.

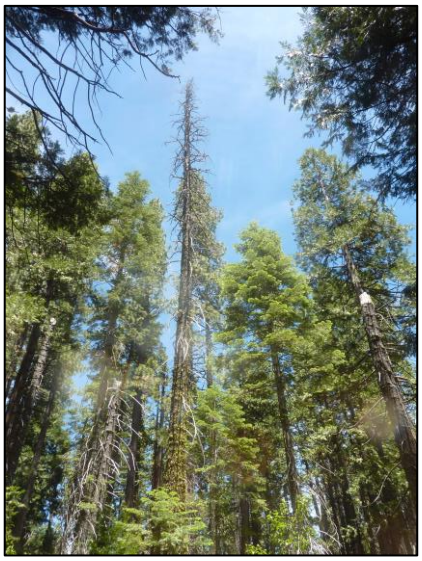


**Figure 2.** Scattered dead white fir killed by fir engraver beetle. Nyack Project, 2019.

White fir canopy cover and white fir regeneration appears to be preventing the establishment of ponderosa and sugar pine seedlings in mixed conifer stands and is contributing to a reduction in black oak due to overtopping. White fir is also likely infected with *Heterobasidion occidentale*, the pathogen that causes Heterobasidion root disease, at most locations contributing to mortality and hazard. We did not make an extensive survey to confirm evidence of root disease during this visit but past visits on this district have identified *H. occidentale* in most locations. White fir mortality was apparent in most locations and occurring at much higher levels than mortality in other conifer species. Evidence of fir engraver beetle (*Scolytus ventralis*) attacks was found on several older and more recently killed trees (Figure 2).

**Figure 3.** Stand of large diameter ponderosa pine. Most are infected with western gall rust causing branch tip and foliage dieback. Opening in foreground is due to recent bark beetle-caused mortality. Nyack project area, 2019.

Plantations are currently overstocked with ponderosa pine that have reached a size class that is highly susceptible to western pine beetle (*Dendroctonus brevicomis*)-caused mortality. Native ponderosa pine stands are also generally overstocked, many infected with western gall rust (*Peridermium harknessii*), and have experienced high levels of mortality during the recent drought (Figure 3). Some of this mortality occurred in and around summer home tracts creating hazard trees that had to be removed (Figure 4).

Mountain pine beetle (*Dendroctonus ponderosae*) was most likely responsible for older sugar pine mortality observed in some Nyack project locations (trees were not accessible). Some of these older dead trees, as well as some living sugar pine, had evidence of white pine blister rust (*Cronartium ribicola*) infections that caused top-kill and branch mortality.

**Figure 4.** Casa Loma summer home tract where ~12 western pine beetle-killed ponderosa pine were removed in 2016.

Other insects and diseases found impacting trees within the Nyack project but not of concern were:

Incense-cedar rust (*Gymnosporangium libocedri*) was found infecting the foliage of incense-cedar and also the alternate host serviceberry (*Amalanchier* spp.).

*Porodaedalea pini* conks were also found in one large ponderosa pine. Trees with this decay fungus may have merchantability negatively impacted and in some cases, with high level infections, could be considered hazards if a target is within striking distance. *P. pini* conks were also found on lodgepole pine growing in the proposed aspen treatment area.

**Figure 6.** Remnant aspen seedlings and saplings (barely visible) growing under conifer canopy. Nyack Project, 2019.

Two aspen stands were observed that were both experiencing competition from conifer species. One was basically a remnant stand along the western edge of the old Gap Fire with only a few seedlings and saplings growing under a conifer canopy (Figure 6). Old dead and down aspen stems were present at this site suggesting this was a much larger and healthier stand many years ago. The other stand south of Nyack and Lake Putt contained many large aspen stems in addition to scattered regeneration. However, most of the stand has been severely encroached by conifers inhibiting healthy regeneration and causing crown decline in mature stems (Figure 7). No major insect or disease pest agents were noted on aspen.

**Figure 7.** Aspen stand with encroaching conifers. Nyack Project, 2019.

**<u>Stand conditions and mortality related to recent and future climate trends</u>**

Most of the forested areas within the Nyack project appear to be at or well above stocking levels that would be considered resilient to insects, disease and drought (Figure 8) and have exhibited an elevated level of tree mortality caused by bark beetles and/or root disease during the recent drought (Table 1 and Figures 9 and 10). This mortality combined with high stand density

has contributed to heavy fuel loading in many areas and a corresponding increase in potential fire behavior.

**Figure 8.** High density mixed conifer stand. Nyack Project, 2019.

These dense stand conditions with high canopy closure also appear to have greatly reduced the amount of sugar pine and ponderosa pine regeneration within the area, shifting stand composition to more shade tolerant tree species.

Predicted climate change is likely to impact trees growing in the Nyack project area over the next 100 years. Although no Tahoe National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (C. Mallek and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Eldorado and Tahoe National Forests and neighboring Sierra Nevada*). The risk of bark beetle-caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant and root diseased white fir. Improving the resilience of the Nyack project to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

**Table 1.** Acres with tree mortality, estimated dead trees per acre, estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (CA Division 2) by water year (Oct-Sept) within the Nyack project area.

| Year | Acres | Dead Trees/Acre | Total # of Dead Trees | PHDI[1] |
|---|---|---|---|---|
| 2018 | 780 | 3.3 | 2,571 | -1.87 |
| 2017 | 1,473 | 21.6 | 31,767 | 2.49 |
| 2016 | 2,689 | 1.9 | 4,985 | -1.78 |
| 2015 | 177 | 1.3 | 239 | -3.03 |
| 2014 | 4 | 1.9 | 8 | -3.12 |
| 2013 | 184 | 1.0 | 188 | -1.62 |
| 2012 | 16 | 1.7 | 27 | 0.37 |
| 2011 | 550 | 1.0 | 552 | 2.59 |
| 2010 | 1,191 | 1.5 | 1,768 | 0.19 |
| 2009 | 21 | 2.6 | 54 | -2.69 |

[1] Palmer drought values show a relationship to tree mortality. PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

## Discussion

The Nyack project area has become very dense with white fir and incense-cedar with the exclusion of fire over the past 100+ years. With such a high percentage of these species in the area, shade intolerant pines and black oaks tend to decline due to competition for sunlight, water and nutrients. The white fir component is also creating stressful competitive growing conditions for old growth pines resulting in elevated levels of pine mortality. Regeneration of

**Figure 9.** Cumulative dead trees per acre mapped by ADS between 2009 and 2018.

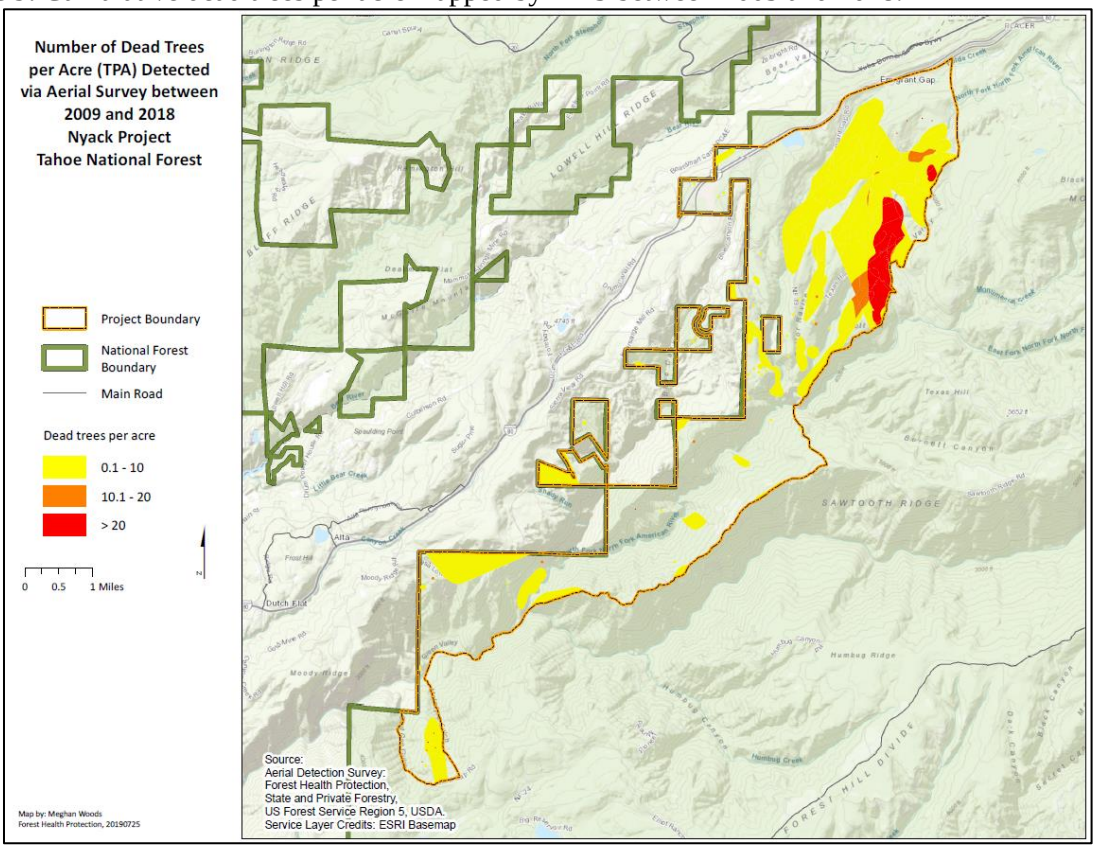
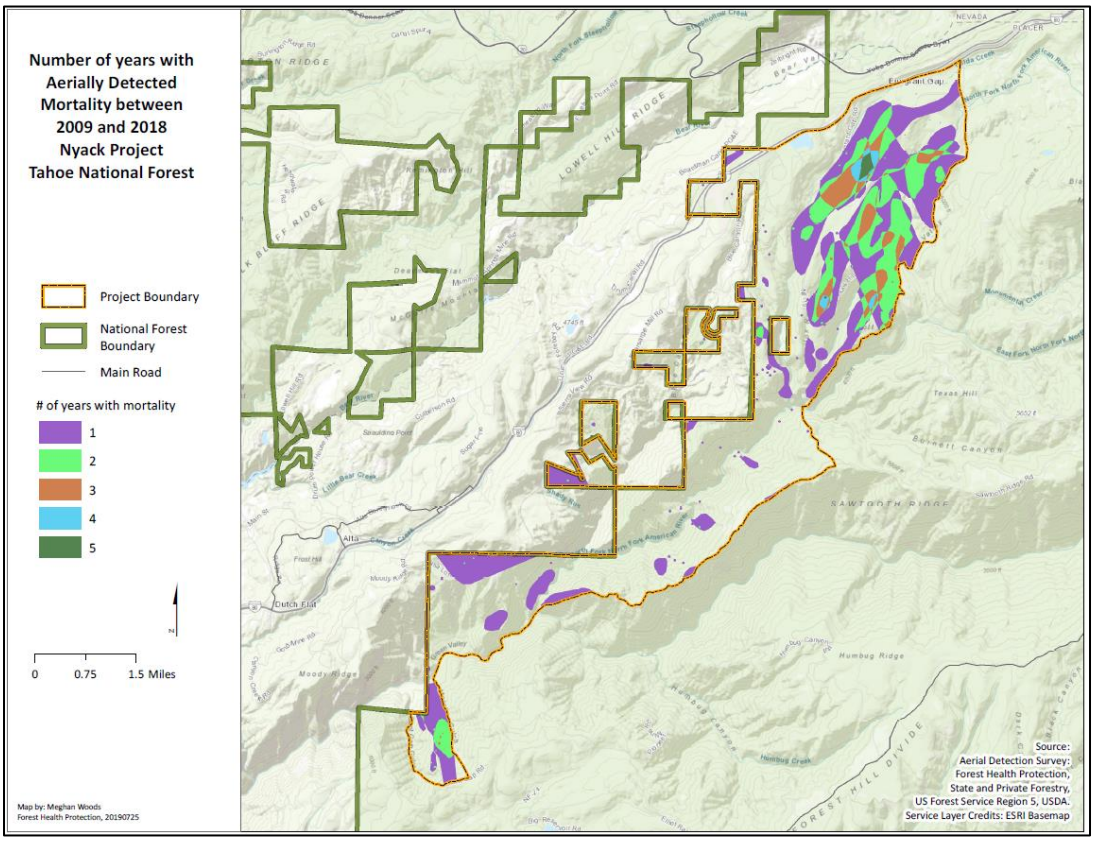



**Figure 10.** Number of years of tree mortality mapped by Aerial Detection Surveys (ADS) between 2009 and 2018.



sugar and ponderosa pines is also limited due to the deep duff and litter that has accumulated in the absence of fire. Heterobasidion root disease in white fir is creating numerous hazard trees in and around undeveloped camping areas by causing mortality and decaying supporting roots of living trees.

The Nyack project area contains many large diameter ponderosa and sugar pine. Thinning treatments that improve growing conditions for these shade intolerant species, such as removing a large percentage of the white fir basal area from around their bases, would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents. Stand level thinning of competing white fir has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (Hood et al 2017).

Thinning treatments are recommended to improve forest health conditions and increase resiliency to disturbance. Treatments should aim to reduce stand density to a level that significantly lowers the risk of bark beetle-caused mortality. In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality for many years. The District should consider an SDI max of 450 for drier mixed conifer (Long and Shaw 2005) on south facing slopes and ridge tops and SDI max 550 (Long and Shaw 2012) for mixed conifer on more mesic aspects and down in drainages.

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as large pines, should benefit by having the stocking around them reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as fork-topped trees. When implementing thinning projects, retaining more drought tolerant species such as ponderosa pine, sugar pine and incense cedar over white fir will increase species diversity and make the stand more resilient to disturbance agents and stresses resulting from predicted climate change. In addition, when selecting trees for removal, preference should be given to trees heavily infected with dwarf mistletoe, root disease and trees infested with bark beetles. Small group selections should be utilized to remove root disease pockets and clumps of trees with heavy dwarf mistletoe infections. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Regional ecosystem restoration goals. Many of these methods are also consistent with past FHP recommendations for thinning in mixed conifer stands and their use is supported for the Nyack project.

The best strategy to decrease the amount of mortality in ponderosa pine plantations and native stands is to reduce stand density to below 230. SDI 230 is the defined threshold for the zone of imminent bark beetle caused mortality. Within this zone, endemic populations kill a few trees but net growth is still positive (Oliver 1995). Thinning stands to this level will reduce the risk of additional bark beetle-caused mortality by reducing tree competition for limited water and nutrients. An emphasis should also be placed on creating spatial heterogeneity and enhancing conditions for other tree species such as Douglas-fir, incense cedar and black oak. Thinning prescriptions should aim to reduce basal area to a range of 60 to 120 sq.ft./acre. This should effectively reduce the risk of significant western pine beetle-caused mortality during future droughts.

The presence of Heterobasidion root disease in white fir should be considered when developing silvicultural prescriptions. Root diseased true fir are at a higher risk for fir engraver attacks than uninfected trees during droughts. Leaving high numbers of root diseased trees will likely lead to higher levels of mortality over the long-term and increased fuels. Leaving these trees will also reduce opportunities for successful regeneration of shade intolerant species that are not susceptible hosts to *H. occidentale*.

The best option for managing *H. occidentale* in white fir is to reduce its overall abundance in the stand and remove severely infected trees. Various sized openings can be created in the stand to facilitate planting of non-hosts such as ponderosa, Jeffrey and sugar pine. Placing these openings on known or suspected root disease pockets will enhance the effectiveness of this strategy for reducing overall infection levels. In addition, greatly reducing white fir stocking in stands that have a non-host overstory component will allow for natural non-host regeneration and create a more resilient species composition over time.

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. An exception to this would be thinning suppressed trees within pure sugar pine groups to reduce inter-tree competition. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

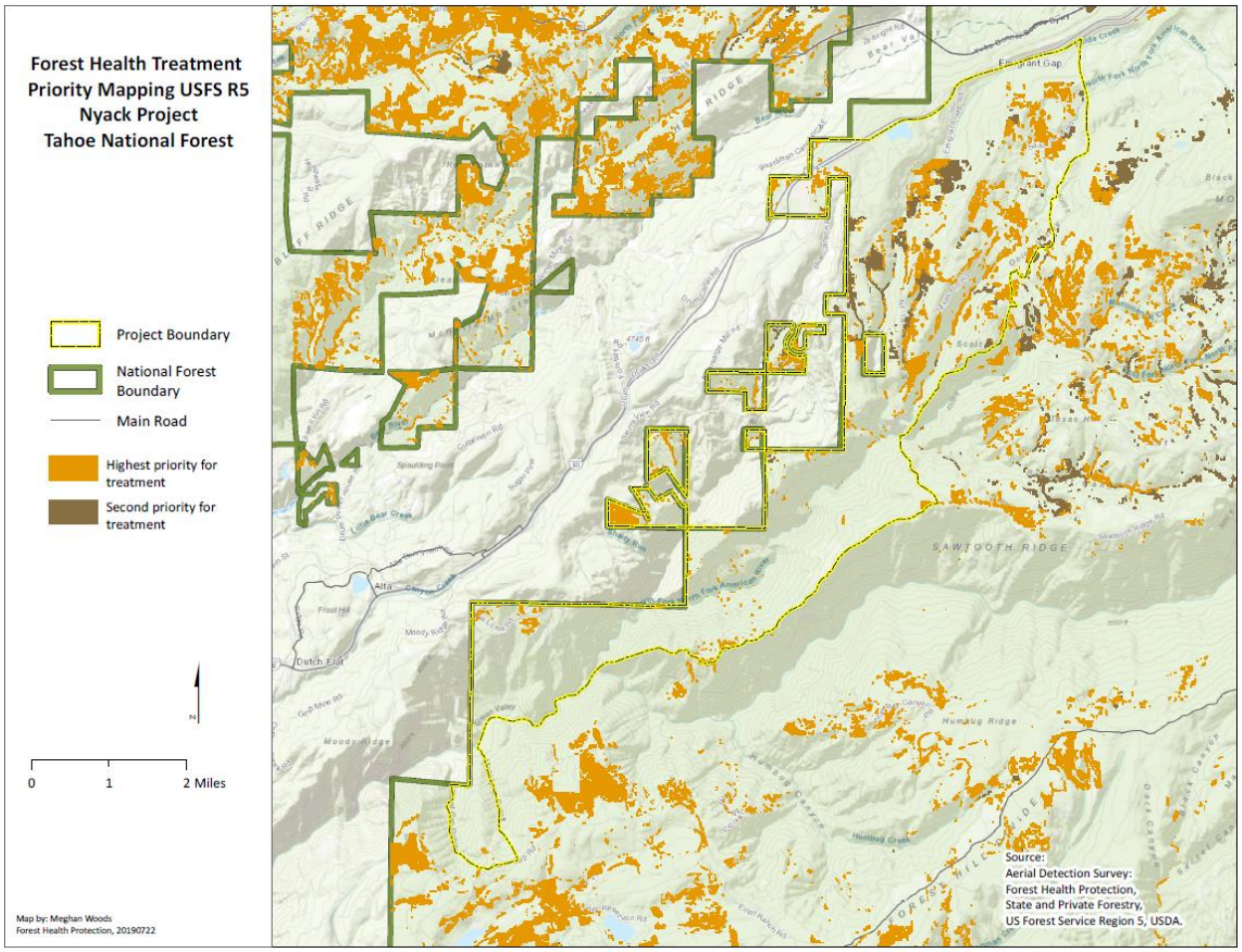
It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14" in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity.

Forest Health Protection recently developed a treatment priority map for Region 5 to help land managers prioritize thinning treatments at the landscape level. This map depicts forested areas on National Forest System lands that are the most susceptible to drought and bark beetle-caused tree mortality based on forest type and stand density. These areas also meet the criteria of existing on slopes <=35% and being outside of wilderness areas, wild and scenic river corridors and designated roadless areas. Additional criteria include not having burned at moderate to high severity since 1998 and not having been thinned since 2005. In addition to being overly dense, these areas have a history of tree mortality during drought resulting in heavy fuel loads and higher risk of stand replacing wildfire. Highest priority areas consist of high density pine stands, pine-dominated mixed conifer stands, and fir-dominated mixed conifer and white fir stands growing on historically pine dominated sites. Second priority areas consist of high density fir-dominated mixed conifer and white fir stands on wetter sites. All mapped stands are California Wildlife Habitat Relationship size class 4, 5 and 6.

Figure 11 shows treatment priority areas within the Nyack project boundary. This mapping effort utilized remotely sensed data to create treatment priority layers for large scale planning and may not be accurate at the stand level. The forest should still use stand records and stand exam data to identify treatment areas and develop silvicultural prescriptions. An ALL LANDS version of the map was also created that includes wilderness areas, wild and scenic river corridors designated

and roadless areas to evaluate stand conditions in these protected areas. It also includes slopes >35% and all land ownerships (Figure 12).

**Figure 11.** Treatment Priority Areas* at risk to bark beetle-caused mortality within and adjacent to the Nyack project area

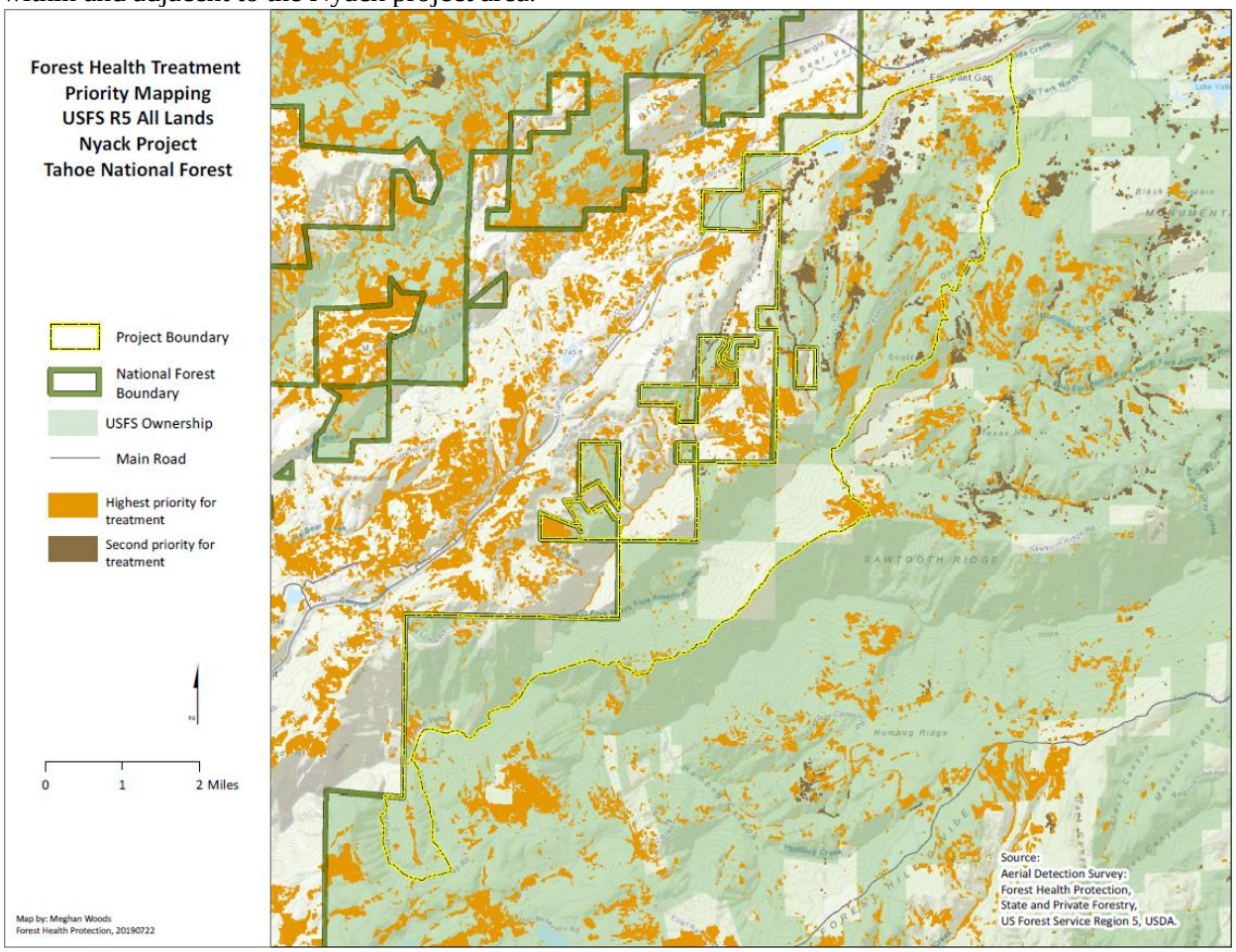



*Highest priority treatment areas include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Wilderness areas, inventoried roadless areas, wild and scenic areas, moderate to high severity burned areas since 1998, areas thinned since 2005, areas with >35% slope and all non-National Forest System lands were excluded from this analysis.

## Considerations for Aspen

Several risk rating criteria have been established for aspen throughout the west. Most of these criteria relate to the abundance of regenerating aspen within a stand, the amount of aspen browsing by wild and domestic ungulates, the condition of the overstory aspen stems and the level of conifer encroachment. Browsing of young aspen combined with conifer encroachment can put an aspen stand at a very high risk of being removed from the landscape. Conifer encroachment and densification often results from the lack of fire disturbance and can eventually shade out aspen stems. Once conifer canopy cover reaches a critical threshold, older aspen stems begin to decline, and regeneration is suppressed.

**Figure 12.** Treatment Priority Areas (ALL LANDS version)* at risk to bark beetle-caused mortality within and adjacent to the Nyack project area.




*Highest priority treatment areas for ALL LANDS version include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Moderate to high severity burned areas since 1998, areas thinned or that experienced stand replacing disturbance such as clear cuts or bark beetle-caused tree mortality since 2005 were excluded from this analysis.

Conifer cover thresholds that result in elevated risk to aspen stand health vary slightly among regional risk rating systems. However, most risk rating systems describe negative impacts to aspen health beginning when conifer cover reaches 25%. This cover level is not part of a continuum of negative affects but rather a critical threshold where at higher levels aspen abundance declines dramatically. Regional Forest Health Protection aspen surveys categorized percent conifer cover as "severe" when it exceeded 25% (Cluck 2012). 50% conifer canopy cover has been described as the highest risk in some rating systems (Bartos and Campbell 1998). Although these thresholds were established to describe high risk situations, any conifer competition will reduce aspen live crown ratio and basal area increment (Berrill and Dagley 2012).

A conifer canopy threshold of 20% has also been observed above which understory vegetation is highly suppressed (Bobette Jones, Unpublished data, Lassen National Forest). Below this threshold there is an exponential increase in the richness and abundance of understory plant

cover. The increase in sunlight and the warming of soils are cited as contributing factors. This 20% threshold is likely relevant to the health and abundance of aspen regeneration.

To maintain and enhance aspen over the long-term, some restoration projects have set post-treatment objectives of 0 - 5% conifer canopy cover or other low levels so as not to exceed 25% within the first 15 years post-treatment (USFS and BLM, CA and NV).

For the larger aspen stand south of Nyack, removing all competing conifers, including a buffer area (~100 feet) would maximize the amount of sunlight reaching the forest floor. This will raise soil temperatures and increase photosynthesis allowing aspen suckers to thrive. Buffer areas should be wider (~150 feet) at the south end of the stand to further increase the amount of sunlight reaching the forest floor. This type of treatment has proven successful in increasing aspen regeneration in as little as three years post-treatment (Jones et al 2005). The removal of all conifers should reduce the rate of conifer reinvasion and the subsequent need for follow-up treatments to remove conifer regeneration.

If some >30" DBH conifers are to be retained, they should be restricted to one or two small clumps or to a few very widely spaced single trees so as not to exceed 5% cover in the stand. Potential leave trees should have minimal direct competition with aspen and/or be concentrated at the north end of the stand to minimize shading effects. Jeffrey and ponderosa pine should be retained over both white fir and lodgepole pine to minimize the rate of conifer reinvasion and in the case of white fir, because they have less leaf area and cast less shade (Gersonde and O'Hara 2005).

The smaller, remnant aspen stand near the Gap Fire may not be suitable for the same scale of conifer removal described above due to its location in an undeveloped camping area where having conifer cover may be a higher priority. It might be more appropriate to remove conifers from a narrower buffer focused on allowing sunlight in from the south and monitoring any resulting aspen release and need for future actions. However, if aspen restoration is the priority for this stand, the full removal of competing conifers as described above will provide the best chance for success.

**Considerations for Rx fire**

If prescribed fire is used as a follow-up treatment to stand thinning or as a standalone treatment, unacceptable levels of large diameter pine mortality may occur depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature Jeffrey, ponderosa and especially sugar pines are susceptible to mortality during prescribed burns because of the deep duff and litter that has accumulated at their base in the absence of fire. These duff mounds typically burn at a slow rate, while maintaining lethal temperatures, causing severe cambium injury. To protect individual large diameter pine from lethal cambium injury, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

The District has successfully conducted a recent prescribed burn in the Big Trees Grove. It was noted during a previous site visit that large pines had duff and litter raked away from the bole prior to the prescribed burn as per prior Forest Health Protection recommendations. It appears that this treatment was very effective in reducing the amount of basal fire-injury and its continued practice is strongly encouraged.

**Potential for funding thought the Western Bark Beetle Program**

Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning and removing green material from the Nyack project area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

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Citations:

Bartos, D.L. and R.B. Campbell. 1998. Decline of quaking aspen in the Interior West – Examples from Utah. Rangelands 20: 17–24.

Berrill, J. and C. M. Dagley. 2012., Geographic Patterns and Stand Variables Influencing Growth and Vigor of Populus tremuloides in the Sierra Nevada (USA). ISRN Forestry, vol. 2012, 9 pages.

Cluck, D.R. 2012. Forest health survey of northeastern California aspen. USDA Forest Service, Pacific Southwest Region, Forest Health Protection Report #NE-SPR-01. 33 p.

Gersonde, R. F. and K. L. O'Hara. 2005. Comparative tree growth efficiency in Sierra Nevada mixed-conifer forests. Forest Ecology and Management, vol. 219, no. 1, pp. 95–108.

Hood, S.M., Cluck, D.R., Jones, B.E., and Pinnell S. 2017. Radial and stand-level thinning treatments: 15-year growth response of legacy ponderosa and Jeffrey pine trees. *Restoration Ecology*. doi:10.1111/rec.12638

Jones, B. E., Rickman, T. H., Vazquez, A., Sado, Y. and Tate, K. W. 2005. Removal of Encroaching Conifers to Regenerate Degraded Aspen Stands in the Sierra Nevada. Restoration Ecology, 13: 373–379.

# Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

### Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

### Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

### Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

# Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host

species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

**Evidence of Attack**

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

**Life Stages and Development**

These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

**Conditions affecting Outbreaks**

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree completion, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

## Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae*, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature

lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

**Evidence of Attack**

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

**Life Stages and Development**

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

**Conditions Affecting Outbreaks**

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

## Heterobasidion Root Disease

*Heterobasidion spp.* is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees

presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.